Luminosity Burn Rate

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General Considerations

The total loss rate of the beams in a collider is equal to the sum of the losses due to the luminosity at the experiment(s) plus a non-luminous loss rate throughout the Tevatron. The non-luminous loss rate is equal to the total loss rate minus the luminous loss rate. We break it down in this (painfully obvious) manner because the luminous loss rate is very accurately known. Each of the colliding beams loses exactly the same number of particles through the luminosity, independent of the intensities of the beams. Therefore we have:

$$R_{NL} = R_T - R_L$$

The luminous loss rate, R_L, can be calculated exactly, knowing the exact cross-section for the interactions of the two beams and the luminosity at the experiment(s):

$$R_L = \sigma \left(\Sigma \mathcal{L}_n \right)$$

where $\mathcal{L}_n$ is the luminosity at the n^{th} experiment and σ is the proton/antiproton cross section:

$$\sigma = 70\ [millibarns] = 7 \times 10^{-26}\ [cm^2]$$

Assuming an exponential decay of particles in each beam (which is locally true at all times), then the lifetime, L, of the beam current from the luminous loss of particles is:

$$L = N / R_L$$

This relationship (and all of the relationships presented here) is true at all times:

$$L(t) = N(t) / R_L(t)$$

Tevatron Specifics

In the Tevatron, we have two beams of particles (protons and antiprotons) that interact at two experiments (CDF and D0). The loss rate of one of the beams from one of the experiments is:

$$R_L\ [particles/hour] = 7 \times 10^{-26}\ [cm^2]\ \mathcal{L}\ [1/(cm^2\ sec)] \times 3600\ [sec/hr]$$

If the luminosity is expressed in units of $[10^{-30}/(cm^2\ sec)]$ and the cross-section is expressed in units of millibarns, and the particle beam intensity units are $[10^9$ particles$]$, then:

$$
\begin{aligned}
R_L\ [10^9\ particles/hour] &= 70\ [mbarn] \times \mathcal{L}\ [10^{30}/(cm^2\ sec)] \times 3600\ [sec/hour] \times \\
&\quad 10^{-27}\ [cm^2/barn] \times 10^{30}\ [luminosity\ units] \times 10^{-9}\ [particles] \\
&= 0.252 \times \mathcal{L}
\end{aligned}
$$

Thus, the total luminous loss rate from the two experiments is:

$$R_L\ [10^9\ particles/hour] = 0.252 \times (\ \mathcal{L}_{CDF} + \mathcal{L}_{D0}\ )\ [10^{30}/(cm^2\ sec)]$$

Assuming an exponential decay in the number of particles from this effect, the luminous lifetime of the proton and the antiproton intensities is:

$$L_P(t)[hours] = N_P(t)[10^9\ particles] / (0.252 \times (\ \mathcal{L}_{CDF}(t) + \mathcal{L}_{D0}(t)\ ))$$
$$L_A(t)[hours] = N_{\backslash A}(t)[10^9\ particles] / (0.252 \times (\ \mathcal{L}_{CDF}(t) + \mathcal{L}_{D0}(t)\ ))$$